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(54) Method of controlling an ultrasonic generator.

(57) The invention concerns a method of controlling the operation of an ultrasonic generator including an ultrasonic oscillator to function at a desired power output, as well as a so controlled ultrasonic generator. The output voltage and/or current is sensed to produce corresponding digital real point voltage and/or current signals which are compared to corresponding digital set point voltage and/or current signals to adjust the frequence and/or pulse width of a digitally controlled ultrasonic oscillator to make real point equal to set point. The invention is particularly useful in ultrasonic cleaning devices or ultrasonic welders.

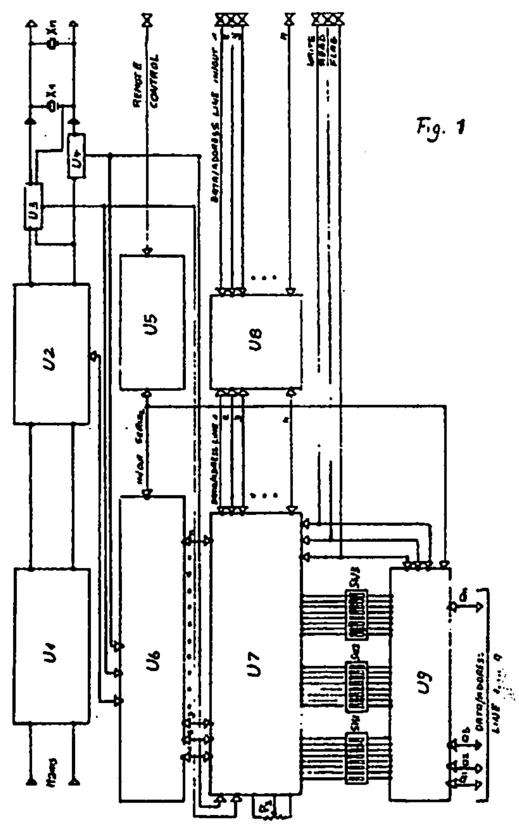

Fig. 1

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The invention generally concerns a control for ultrasonic generators and more particularly a control for the ultrasonic generator of ultrasonic cleaning equipment.

The power of an ultrasonic generator is rather dependent on a large number of parameters which may adversely affect the operation of the generator. Through its transducers the generator emits a quantity of acoustic energy to a medium; in the case of cleaning, this is usually a liquid in which the objects to be cleaned have been placed. The energy emitted to the medium accelerates the molecules in the medium, creating intramolecular spaces which implode if sufficient energy is supplied. The resulting shockwaves knock particles off the objects placed in the liquid (cleaning), or alternatively it may happen that objects are damaged (by erosion) or even destroyed. The quantity of energy applied is consequently important and has to be reproducible under all circumstances. Up until now ultrasonic equipment has generally been overdimensioned so as to ensure at least an acceptable cleaning result, with the risk that something might occasionally go wrong.

The power emitted by an ultrasonic generator depends in a cleaning device on a number of different parameters, such as the liquid used, the height of the liquid column, the viscosity, the temperature, surface tension of the liquid, loading of the cleaning tank, mains supply voltage, etc. These parameters do not only affect output power of the generator and cleaning power, but also the power input to the generator and its ability to transfer energy into the medium. Medium is to be understood to mean the attached tank provided with any form of transfer element known as transducer.

One approach to keep the power input to the ultrasonic generator of an ultrasonic cleaning device within acceptable limits while keeping the power output constant is disclosed in DE-A-33 17 045. This publication proposes to measure the actual power transferred by the ultrasonic generator to the ultrasonic transducer, to compare the actual power with a desired power providing the required cleaning effect and to obtain a difference signal which is used to adjust the frequency of a voltage controlled oscillator so as to keep the power output at the desired power output. This publication allows to keep constant the power output of the generator at a desired value which is to be adjusted before putting the ultrasonic cleaning device into operation under consideration of the above parameters. As these parameters change during operation, the adjusted desired value is no longer in agreement with the desired value for the changed parameters so that the ultrasonic cleaning device may then not operate satisfactorily as regards cleaning effect and power input to the ultrasonic generator.

The object of the invention is to improve the operation of ultrasonic generator at a constant power output, especially cleaning devices as regards cleaning effect and power output from the ultrasonic generator.

This object is achieved in a method according to the preamble of claim 1 and a control according to the preamble of claim 6 by means of the features claimed in the characterizing part of claims 1 and 6, respectively.

Embodiments of the invention are claimed in the sub-claims.

The invention will now be described by way of example with reference to the accompanying drawings, wherein:

Fig. 1 is a schematical representation of a circuit diagram of a preferred embodiment of the ultrasonic generator according to the invention; and

Fig. 2 is a graph showing the impedance of a ceramic transducer element.

In Fig. 1 is shown schematically an overall general circuit diagram of a preferred embodiment of an ultrasonic generator according to the invention. The ultrasonic generator comprises an ultrasonic frequency power converter or oscillator U2 which is connected to a power supply U1 fed by mains. The power supply U1 supplied in an appropriate form the energy needed to operate the ultrasonic generator. It comprises e.g. mains filter (if necessary), transformer(s) or a switch-mode power supply, rectifiers and if necessary smoothing filters. Its components do not form a part of the claimed invention.

The oscillator or ultrasonic frequency power converter U2 comprises a digitally controlled oscillator producing output power at a frequency Fo. The power output from the oscillator may be varied by changing or shifting its oscillation frequency or keeping its frequency constant at Fo, but modulating the pulse width thereof.

Ultrasonic transducers $X_1 ... X_n$ are connected in parallel across the output terminals of the oscillator U2. The number of transducers $X_1 ... X_n$ is determined by the particular application. The transducers may exhibit inductive, capacitive or resistive behaviour.

The voltage converter U3 is connected across the output terminals of the oscillator U2 to convert the voltage supplied to the transducers $X_1 ... X_n$ into a digital real point voltage signal.

A current converter U4 is connected between the oscillator U2 and the transducers $X_1 ... X_n$ to convert the current supplied to the transducers $X_1 ... X_n$ into a digital real point current signal.

The voltage and current converters U3 and U4 may also form a single power converter generating

a digital real point signal.

The digital real point (voltage and current) signals are compared with corresponding set point signals in a comparator which may comprise a CPU U7 of a data processing system to produce a control signal when the real points do not agree with the set points. This control signal is fed to the oscillator U2 to either adjust the frequency thereof or to modulate the pulse width of its frequency to make the real point equal to the set point.

The CPU U7 is connected through a series/parallel addressed frequency oscillator U6 programmable for pulse-width modulation and/or frequency shift to the ultrasonic frequency power converter or oscillator U2.

The hardware-based logic and/or central processor (CPU)U7 is connected in a preferred embodiment to a bidirectional input/output point U8 for parallel data transmission and via program switches SW1...SWn to a program instructor U9 comprising hardware, PROM, EPROM, CPU, software, etc. The purpose of the unit U9 is to convert in a particular system to which the ultrasonic generator is applied to the operation parameters of the system and to send them via the CPU U7 to the series/parallel addressed frequency oscillator U6 in the preferred embodiment of the invention.

The operation parameters are entered into unit U9 through data/address lines 1...n.

The bidirectional input/output port U8 as parallel data transmission allows to enter data into the CPU under the control of the WRITE line from external sources or to display data in the CPU externally under the control of the READ line. The FLAG indicates the digital cycle in which the CPU is located and enables this to be changed.

The CPU U7 is also connected to an RSC IN/OUT converter U5 programmable for the correct RSC code and band rate for connection to a serial transmission line for peripheral connections, e.g. for changing the set point values by a remote control via a telephone line.

The CPU U7 is also connected to a potentiometer P1 for tuning the oscillator to a fundamental frequency Fo.

Fig. 2 shows a graph for ceramic transducer element showing the effect of the frequency of the impedance of the transducer; the centre frequency can be influenced by a pure Fo shift, but also by a fixed Fo which changes in pulse width. The same applies to inductive or magnetostrictive transducer elements. In the case of ceramic elements the voltage is virtually constant. For magnetostrictive elements the current is virtually constant. For ceramic elements the formula U^2/Z_c = P-out can mainly be used, whereby the voltage dominates. For magnetostrictive elements the formula is I^2 x Z1 = P/out, with the current dominating. So in these cases it will be sufficient to activate either the voltage inverter U3 or current inverter U4. The phase angle between current and voltage is practically identical in both cases, except that in the one case it is leading and in the other case it is lagging. In cases where the transducers behave resistive, both the I-converter and the U-converter are made active.

It is clear from the graph that the transducers have a natural frequency response in respect of their load; this has been known for decades, and so it is not a part of the invention to change the frequency Fo of the oscillator, but only the way in which the generator is controlled to obtain this change.

Briefly, the energy emitted by ultrasonic oscillator U2 is measured in terms of current and/or voltage depending on the transducers $X_1...X_n$ and converted in converters U3 and/or U4 into a digital real point (voltage and/or current) signal which is compared in comparator or CPU U7 with a set point value. The set point value may be obtained from "data/address" buses , PROM or software. Based on the comparison in CUP U7 the frequency Fo of the oscillator U2 is either shifted or a pulse width modulation is applied to the frequency Fo of the oscillator U2 through unit U6 to make the real point equal to the set point. The digitally controlled oscillator may have a frequency range approximately from 20,000 to 100,000 Hz.

The digital control used in controlling the ultrasonic generator of the invention is faster, more accurate easier to control then prior art control systems. In the preferred embodiment it is basically a cybernetic circuit which bears some resemblance to the natural motional feedback that occurs in existing life-forms. Through the data/address buses this system hay eyes, ears, hands and feet and is only limited by the available memory storage capacity, which can of course easily be expanded.

Claims

1. A method of controlling the operation of an ultrasonic generator including an ultrasonic oscillator to function at a desired power output,characterized by the steps of
sensing the output voltage of the ultrasonic oscillator and generating a digital real point voltage signal commensurate therewith; and/or
sensing the output current of the ultrasonic oscillator and generating a digital real point current signal commensurate therewith;
comparing the digital real point voltage and/or current signals with corresponding digital set point voltage and/or current signals and generating a

digital signal when said real and set point signals do not agree, and
changing the frequency of a digitally controlled oscillator or modulating the pulse width thereof to thereby make the real point equal to the set point.

2. The method according to claim 1, further comprising the step of manually or continuously automatically adjusting the set point as a function of operation parameters of an ultrasonic systems using said ultrasonic generator.

3. The method of claim 2, wherein said system is an ultrasonic cleaning system and said set points are continuously adjusted as a function of the liquid used, the viscosity, the temperature and/or the surface tension thereof, and/or the height of the liquid column.

4. The method of claim 2, wherein said system is an ultrasonic welding system and said set points are adjusted as a function of the materials to be welded.

5. The method of claim 3 or 4, wherein said set points are adjusted as a function of the mains supply voltage.

6. An ultrasonic generator comprising an ultrasonic oscillator and ultrasonic transducer means driven by said ultrasonic oscillator and ultrasonic oscillator output sensing means, characterized in that said ultrasonic generator comprises a digitally controlled oscillator, said sensing means generate a digital real point output signal, digital means for comparing the digital real point output with a set point output signal and means for shifting the frequency of the digitally controlled oscillator or modulating its pulse width to keep the real point signal equal to the set point signal.

7. The ultrasonic generator of claim 6, wherein said sensing means comprise a voltage sensing means for generating a digital real point voltage signal and/or a current sensing means for generating a digital real point current signal.

8. The ultrasonic generator of claims 6 or 7, wherein said comparing means comprises a CPU of a signal processing means.

9. The ultrasonic generator of claim 8, comprising input means to said CPU for inputting operation parameters of the system using the ultrasonic generator.

10. The ultrasonic generator of claim 9, wherein said system comprises an ultrasonic cleaning system and wherein said operation parameter include the cleaning medium, the viscosity, temperature and/or surface tension thereof, and/or the height of the column of the medium.

11. The ultrasonic generator of claim 9, wherein the system comprises an ultrasonic welding system and wherein said operation parameters include the materials to be welded.

12. The ultrasonic generator of claim 10 or 11, wherein said operation parameters include the mains supply voltage.

13. The ultrasonic generator of any one of the claims 7 to 12, comprising an input to the CPU for remote control.

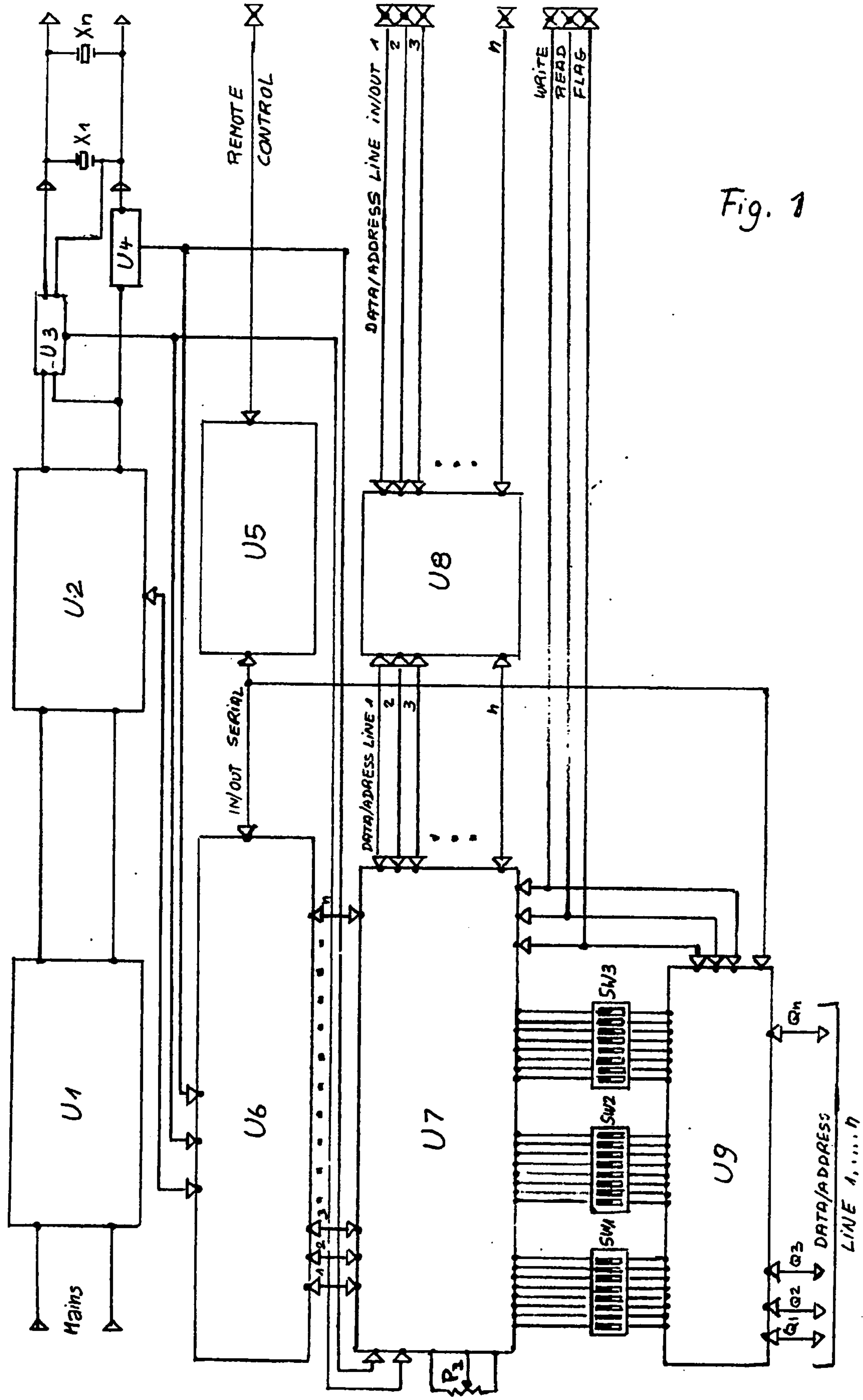
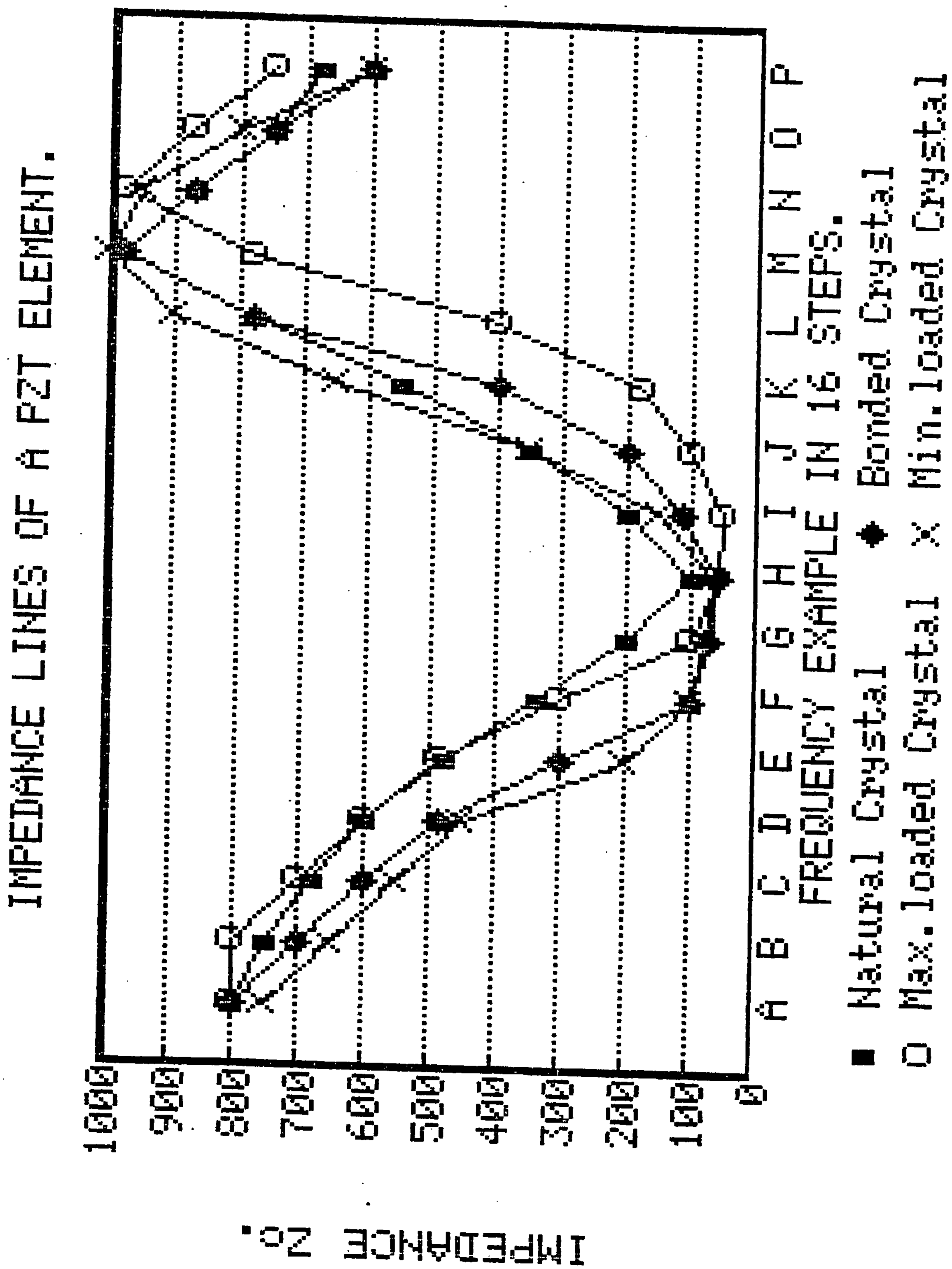

Xn
X1
U4
U3
U2
U1
Mains
REMOTE CONTROL
U5
IN/OUT SERIAL
U6
DATA/ADDRESS LINE IN/OUT 1
2
3
n
U8
DATA/ADDRESS LINE 1
U7
WRITE
READ
FLAG
SW3
SW2
SW1
R1
U9
Qn
Q3
Q2
Q1
DATA/ADDRESS LINE 1,...,n

Fig. 1

Fig. 2


IMPEDANCE LINES OF A PZT ELEMENT.
1000
900
800
700
600
500
400
300
200
100
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A B C D E F G H I J K L M N O P
FREQUENCY EXAMPLE IN 16 STEPS.
Natural Crystal
Bonded Crystal
Max. loaded Crystal
Min. loaded Crystal
IMPEDANCE Zo.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 87 63 0233

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A,D	DE-A-3 317 045 (MARTIN WALTER ULTRASCHALLTECHNIK GmbH) * Abstract; figure 1 * ---	1	B 06 B 1/02
A	US-A-3 544 866 (McLEROY) * Abstract * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			B 06 B G 10 K B 23 K B 08 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-07-1988	ANDERSON A.TH.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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